∞'P' { Four of neck planes...................... also cheek by back jaw and posterior skull by ear...................................... } Prism.

Of course it is understood that m, n, t, r, &c., are simply coefficients by means of which to derive all the forms to which they refer in parameter values from some typical P whose parameter values must be assumed as normal.

The whole object is merely to enable the sculptor to give each plane a name and not entirely an arbitrary one.

On a Series of Chemical Analysis of Siluro-Cambrian Limestone Beds in Cumberland County, Pennsylvania.

By J. P. Lesley.

(*Read before the American Philosophical Society, December* 21, 1877.)

The mixture of magnesia with lime in dolomite rocks has always stimulated and baffled geological speculation, and given birth to opposite hypotheses; some of them, such as that of the issue of magnesium vapors from the interior of the earth, absurd enough; others, such as that recently propounded by Mr. W. L. Green, British Minister at Honolulu, who derives the magnesia from olivine in lava, very suggestive of truth.

I have long felt that no sound basis for speculation had been secured so long as the collection of facts consists merely of analyses of sporadic specimens of limestone and dolomite rocks. I therefore directed Mr. R. H. Sanders, of the Pennsylvania Geological Survey, to make a careful section of the Siluro-Cambrian strata exposed for a quarter of a mile along the west bank of the Susquehanna River, opposite Harrisburg, both by the deep cuttings of the North Pennsylvania Railroad, and by quarries. This was done in connection with his field work in Cumberland County.

Mr. Joseph Hartshorne was also directed to take duplicate samples from every stratum, thick or thin, in this section; one at railway grade, and the other at the top of the exposure (sometimes 30′ high); to analyse them in the laboratory of the Survey at Harrisburg. This he has done, and is still doing, devoting his entire time and attention to the selection of the samples in *situ*, and their determination in the laboratory. In all cases of doubt the analyses have been duplicated and sometimes triplicated; and a report of all analyses as fast as made is forwarded to headquarters.

Of the whole conformable series of beds numbered from the topmost (dipping about 30° to the south) No. 1 down to No 98, Mr. Hartshorne has as yet only analysed from No. 1 to No. 46. But the generalization which the series foreshadows is so interesting and novel that I venture to present it to the notice of the Society, and its correspondents.

Mr. Sanders' report of the beds is as follows:

No. of bed.	Thickness in feet and inches.	Lithological character.
1	3′ 0″	Limestone, light gray.
2	2′ 9″	" gray.
3	3′ 6″	" dark blue.
4	4′ 6″	" dark gray.
5	8′ 1″	" dark blue, with numerous lenses of flint.
6	2′ 0″	" dark blue.
7	0′ 9″	" light blue.
8	2′ 3″	" light blue; seams of calcite; fault of 13″.
9	2′ 8″	" dark blue.
10	13′ 8″	" dark gray; some calcite.
11	5′ 7″	" dark gray; calcite.
12	3′ 8″	" gray.
13	12′ 8″	" gray.
14	4′ 4″	" dark gray.
15	2′ 9″	" dark blue.
16	2′ 8″	" dark blue.
17	1′ 0″	" light gray.
18	1′ 1″	" light gray; with calcite.
19	2′ 0″	" light gray.
20	1′ 2″	" dark gray.
21	2′ 0″	" dark blue; with some flint.
22	1′ 4″	" light gray; with some flint.
23	6′ 11″	" dark blue; with streaks of flesh colored.
24	0′ 7″	" light gray; with a great deal of calcite.
25	0′ 9″	" dark blue.
26	1′ 11″	" dark blue.
27	6′ 5″	" dark blue; seams of calcite.
28	4′ 1″	" light gray.
29	2′ 7″	" dark blue.
30	1′ 0″	" light gray; large amount of calcite.
31	3′ 2″	" dark blue; few veins of calcite.
32	6′ 8″	" dark blue; few veins of calcite.
33	0′ 10″	" light gray.
34	1′ 7″	" dark gray; calcite.
35	0′ 4″	" dark blue; with white spots.
36	4′ 6″	" dark blue.
37	0′ 10″	" light gray; with seams of calcite.
38	4′ 3″	" dark blue.
39	3′ 2″	" light gray; seams of calcite.
40	1′ 2″	" dark gray; seams of calcite.
41	2′ 3″	" bluish black.
42	0′ 3″	" bluish black.
43	3′ 6″	" bluish black; black flint.
44	0′ 10″	" dark gray; with calcite.
45	0′ 5″	" light gray.
46	0′ 2″	" light gray; with calcite.
47	0′ 6″	" light gray; with calcite.
48	1′ 10″	" dark gray; black flint.

No. of bed.	Thickness in feet and inches.		Lithological characters.
49	4′ 0″	"	light gray; seams of calcite.
50	0′ 5″	"	light blue.
51	5′ 2″	"	dark blue; few seams of calcite.
52	0′ 11″	"	light blue.
53	1′ 0″	"	gray; veins of calcite.
54	1′ 10″	"	gray; veins of calcite.
55	2′ 0″	"	light and dark gray.
56	1 10″	"	light blue.
57	0′ 10″	"	light gray; spots of calcite.
58	2′ 4″	"	dark gray; lenses of flint.
59	5′ 8″	"	light gray.
60	6′ 4″	"	dark blue; masses of flint.
61	1′ 9″	"	light gray; seams of calcite.
62	14′ 0″	"	dark blue.
63	2′ 10″	"	dark gray; much flint.
64	6′ 6″	"	dark blue; cleavage planes calcite.
65	3′ 8″	"	light gray; full of calcite.
66	4′ 6″	"	dark blue; with calcite.
67	5′ 6″	"	gray, with a reddish tinge.
68	3′ 7″	"	light gray.
69	5′ 0″	"	dark blue, with yellow streaks.
70	2′ 3″	"	light gray.
71	1′ 2″	"	bluish black.
72	2′ 3″	"	light gray; calcite.
73	3′ 0″	"	dark gray.
74	6′ 0″	"	dark blue; some little calcite.
75	5′ 3″	"	light gray; seams of calcite.
76	1′ 9″	"	light gray.
77	6 3	"	light gr y.
78	7 3	"	light gray, part flesh colored.
79	6 8	"	dark blue.
80	11 5	"	light gray, streaks of flesh colored.
81	1 5	"	light gray.
82	5 9	"	dark blue.
83	1 5	"	light gray.
84	2′ 5″	"	dark gray.
85	4′ 9″	"	dark blue.
86	5 10	"	very dark blue.
87	6 5	"	light gray; full of calcite.
88	17 8	"	dark blue.
89	3 9	"	dark gray; some calcite.
90	5 0	"	dark gray, and flesh colored.
91	8 9	"	dark gray.
92	1 2	"	light gray.
93	26 6	"	dark gray (several beds all alike).
94	5 6	"	light gray; calcite.
95	4 6	"	dark gray.
96	11 3	"	dark blue.
97	8 0	"	dark gray.
98	30′ 4″	"	dark gray.
	425′ 9″		

This last and lowest bed visible at the north end of the exposure is calculated by Mr. Sanders to lie 1280 feet above the lowest bed of the whole series of Cambro-silurian limestones, or in other words, 1280′ higher in the Palæozoic system than the Potsdam Sandstone. This calculation is made by projecting curves according to all the observed dips between the north end of exposure, and the edge of the slate country to the north, checked by dips in a series of exposures on the east bank of the river. It is not necessary to go here into a discussion of the existence of a great upthrow fault between the limestones and slates.

The topmost bed, No. 1, of the series is therefore $1280' + 426' = 1706'$ above the Potsdam Sandstone.

The upper limit of the limestones, where they pass conformably beneath the Utica or Hudson River slates, is seen several miles down the river. By projecting dip-curves in the interval Mr. Sanders measures an additional thickness of limestones amounting to 1819 feet.

The total observed thickness of the great limestone formation (No. II of the old Pennsylvania Survey including representatives of Calciferous, Chazy, Birds' eye, Black-river, and Trenton limestones) is 3535′.

The beds selected for examination lie therefore a little below the middle horizon of the mass, and undoubtedly belong to the "Calciferous Limestone Formation" of the New York geologists, the Magnesian Limestone Formation of the Western geologists.

All these beds contain carbonate of magnesia; but while in some of them the percentage of this element is very low, as low as 1% or 2%, it rises in others very high, even to 37%. Some of the beds may therefore be spoken of as pure limestones, and others as true dolomites. The remarkable features however are: 1. That by virtue of some unknown law very few of the beds seem to occupy an intermediate place or exhibit a mixed or moderate character; and 2. That the two extreme types alternate, every other bed being limestone, and every other bed being dolomite.

The astonishing regularity of this law is not so evident to one who merely reads the table of analyses, but unmistakably forces itself upon the attention if the reader converts the table into a diagram. Whether the law rules over the sequence of the whole series of 98 beds is yet to be discovered. Even if it does we cannot safely formulate it as a law determining the distribution of the carbonate of magnesia throughout the 3535 feet of Siluro-cambrian limestones. But such a law, whatever be its restrictions, demands the earnest attention of chemists and geologists.

The following table then gives the percentage of *carbonate of magnesia* in each bed: in column A at railway grade; in column B at the top of the cut, or quarry. Also, the *carbonate of lime,* column C, railway grade, column D, top of cut. Also, *insoluble material,* column E, at grade, column F, at top.

Number of bed.	Carb. Magnesia. A	B	Carb. Lime. C	D	Insol. matters. E	F
1	36.9	38.3	58.3	57.0	4.6	4.0
2	38.5	3.97	55.6	56.2	5.3	3.8
3	38.1	2.7	56.3	87.6	4.7	8.8
4	1.8	1.9	94.0	97.1	3.8	1.4
5	1.4	0.7	96.4	97.3	1.9	2.1
6a } 6	1.4	1.3	95.5	97.6	1.5	1.0
6b } 6	3.6	3.7	87.1	87.4	9.7	9.0
7	14.5	7.5*	82.3	87.5*	3.1	3.9*
8	24.8	27.1†	68.3	67.6†	5.5	5.4†
9	8.1	8.2	90.7	90.3	1.9	5.7
10	1.8	1.3	97.6	96.7	1.1	2.2
11	32.4	20.0	66.0	75.9	1.6	2.5
12	2.3	1.9	96.8	97.3	1.2	1.4
13	2.4	11.9	95.8	83.9	1.8	3.4
14	4.4	1.0	92.4	97.3	3.4	1.8
15	1.3	2.0	91.8	97.1	1.1	1.2
16	1.1	33.4	97.7	60.1	1.1	5.9
17	1.2	4.3	97.0	93.5	1.3	2.1
18	30.8	34.5	65.3	62.3	3.5	2.9
19	3.0	0.8	96.4	98.7	0.7	0.5
20	18.5	24.3	76.3	71.5	5.3	4.2
21	3.8	1.6	93.7	97.4	1.9	1.3
22	30.8	28.6	65.3	64.3	3.4	6.5
23	1.6	2.0	94.8	93.1	3.9	4.8
24	23.8	23.6	68.9	68.9	7.4	6.3
25	6.8	6.3	90.0	71.0	3.4	22.9
26	28.5	18.1	63.3	75.7	6.2	5.6
27	6.7	2.0	81.3	94.2	12.0	4.0
28	29.1	31.4	65.0	62.4	5.4	5.4
29	1.1	1.5	98.9	97.9	0.6	0.9
30	27.7	25.1	61.0	64.3	10.9	10.3
31	1.7	1.0	96.7	97.6	1.7	1.8
32	1.6	1.2	97.6	96.3	1.1	1.5
33	18.8	25.7	75.2	67.2	4.7	5.9
34	15.0	3.5	81.6	93.6	2.7	2.8
35	17.0	13.3	79.7	83.0	2.9	2.8
36	8.2	1.6	87.7	98.7	1.6	0.3
37	33.6	37.3	61.5	5.63	4.7	6.1
38	1.7	2.2	96.9	95.8	1.4	1.9
39	35.0	34.8	55.6	57.2	6.9	6.5
40	1.3	1.3	92.8	91.0	1.3	7.9
41	22.5	28.2	73.6	6.55	3.4	4.8
42	2.0	——	96.2	——	2.4	——
43	1.7	7.6	97.2	90.1	0.7	1.8
44	29.5	27.1	63.4	68.2	6.4	3.6
45	1.9	2.2	94.3	95.3	3.5	2.2
46	33.2	26.9	57.8	66.2	8.0	5.7
* Bed 7	3d analysis	21.7		72.2		6.3
† Bed 8	" "	30.9		63.6		5.1

*†The third analysis was of a sample intermediate between the top and bottom of the exposure.

The percentage of *Carbonate of iron* in these beds runs thus in the samples taken at railway grade: .... .725 .638 .363

.406	.058	.914	.203	.319	.566	.102
.044	.015	.073	.073	.058	.029	.450
.203	.682	.123	.131	.087	.392	.174
.460	.189	1.189	.290	.696	.058	.219
.363	.110	.885	.653	.580	.479	.725
.479	2.422	.218	.617	.058	.040	1.310
.334	1.438					

and the samples at the top exhibit about the same variations within the same limits, bed 16 showing 1.044; bed 39, 1.994; bed 41, 1.523; bed 44, 1.537; bed 46, 1.552, and all the rest falling below one per cent.

The percentage of *Alumina* is extremely low, being *nil* in many of the beds, and .002 .020 .030 .180, rising in four instances to .300 .350 .479 and .600 in the first set of samples, and to .390 in one instance in the other set.

The percentage of *Sulphur* in the first set of samples taken from the bottom of the cuttings is as follows: .... .048 .050 .044

.119	.070	.050	.032	.058	.076
.028	.589	.042	.034	.027	.018
.040	.095	.088	.076	.025	.106
.016	.095	.089	.065	.069	.017
.176	.095	.081	.128	.150	.080
.048	.133	.130	.141	.051	.072
.071	.115	.059	.092	.035	.071
.096	.096	.075			

and in the second set keeps about the same range, but never exceeds .200 except in the *third* (2.50), twenty-seventh (.222), forty-fifth (.307), and thirty-third (.438) beds.

The percentage of *Phosphorus* in the first set is as follows: ....

.006	.008	.003	.013	.006	.trace
.trace	.none	.008	.trace	.006	.014
.006	.015	.008	.003	.trace	.003
.011	.006	.006	.trace	.trace	.trace
.trace	.trace	.trace	.none	.none	.none
.010	.none	.none	.005	.none	.none
.none	.none	.none	.018	.none	.003
.006	.trace	.004	.011	.trace	.trace

the highest being .018.—In the second set three go up to .010, two others to .013, one to .015, one to .017, and one as high as .061.

The percentage of Carbonaceous matter in the first set ranges as follows :

.094	.012	.472	.166	.128
.090	.250	.152	.150	.098
.124	.128	.050	.208	.138
.076	.040	.040	.020	.036
.010	.016	.160	.060	.130
.030	.590	.123	.200	.018
.268	.082	.100	.266	.208
.086	.054	.032	.060	.288
.trace	.174	.trace	.126	.064
.104	.050			

the highest being .472 and .590.—In the second set the amount of carbonaceous matter rises to .212 (45th bed) .220 (6th *b*) .300 (6th *a*) .450 (28th) .540 (24th).

All attempts to generalize the results must be deferred until the series of analyses shall be completed.

NOTE.—January 30, 1878. The following additional analyses have been received from Mr. Hartshorne. Bed 6 was subdivided into an upper and a lower portion, although no bed plate subdivision *in situ* could be detected ; solid limestone was seen graduating downwards into laminated limestone, almost a slate. The excess of insoluble materials in 6*b*. over 6*a*. shows the cause of the structure :

6*a*.	3.6	4.0	89.9	92.0	5.7	4.1
6*b*.	3.2	4.1	67.2	66.5	26.6	25.3
47	32.4	31.7	60.4	62.0	5.3	5.1
48	3.2	2.9	92.9	95.7	3.0	1.7
49	31.9	23.7	61.4	68.9	5.3	7.2
50	10.0	7.0	84.1	88.7	4.7	3.4
51	1.3	1.2	98.2	97.9	1.2	0.7
52	10.8	13.4	79.8	79.5	8.6	6.9
53	24.2	23.2	66.9	66.1	7.4	9.7
54	2.4	2.3	91.6	91.0	5.9	6.8